

# MEDICAL EFFECTS OF CHEMICAL WEAPONS



3D Marines

# Terminal Objectives

- Understand the physiologic effects of chemical weapons
- Understand the triage, diagnosis, and treatment of chemical weapons casualties.



# DEFINITION

- **A chemical weapon is a chemical used by a military force to kill, injure, or incapacitate troops by their physiologic effects.**
- **Distinguished from other chemicals used by the military, such as defoliants, pesticides, smokes or riot control agents.**
- **Use regulated by treaty.**



# **POLICY**

- **Chemical weapons will not be used by U.S. Armed Forces, even in retaliation for a chemical weapons attack on our troops.**
- **Current chemical weapons stockpiles are being destroyed.**



# HISTORY

- 423 BC, Peloponesian War, smoke directed thru hollowed beams
- 6th Century, “Greek fire” rosin, sulfur, pitch, naphtha, lime, saltpeter
- 1812 Britain considered sulfur laden ships
- Chlorine shells considered in Civil War
- Crimean



# HISTORY

- **WWI Germans develop portable flame thrower**
- **15 April 1915, Germans release chlorine gas at Ypres, 800 deaths, 15,000 retreat**
- **12 July 1917, sulfur mustard, 20,000 casualties**
- **Between WW's, Britain in Afganistan, Spain in Morocco, Italy in Ethiopia, Germans develop nerve agents**



# HISTORY

- **SS Harvey, 1943, Italy**
- **? Egypt uses mustard in Yemen in 1963**
- **Iran-Iraq War, mustard, nerve agents, cyanide**
- **UN discovers nerve agents and mustard stockpiled in Iraq after Desert Storm**



# MORE DEFINITIONS

- States: Solid, liquid, gas. After detonation from a munitions container, agents are usually aerosols.
- Volatility - the speed with which an agent evaporates, inversely related to persistence
- LD50 - lethal dose of liquid agent that will kill 50% of a group
- LCt50 - lethal concentration times time product of vapor or gas exposure that will kill 50% of a group





# **A SUGGESTED APPROACH**

- **A Agent(s)**
- **S State(s)**
- **B Body site(s)**
- **E Effect(s)**
- **S Severity**
- **T Time Course**
- **O Other diagnoses**
- **S Synergism**



# LUNG (CHOKING) AGENTS

- Chlorine (CL), Phosgene (CG), Diphosgene (DP)
- Phosgene is prototype agent, first synthesized 1812, first utilized in Verdun in 1917 by Germans, 80% of chemical deaths in WWI
- Nonpersistent agent (BP 7.5 C), odor of sweet, newly mown hay, odor threshold 1.5 mg/m<sup>3</sup>, LCt<sub>50</sub> 3200 mg-min/m<sup>3</sup>



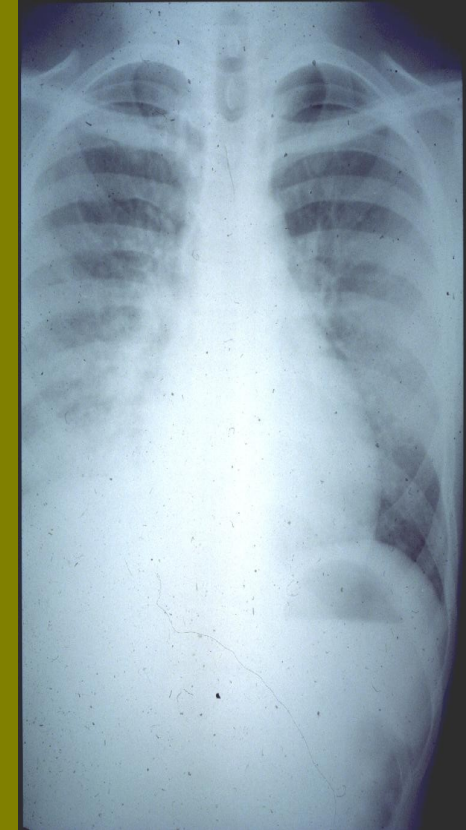
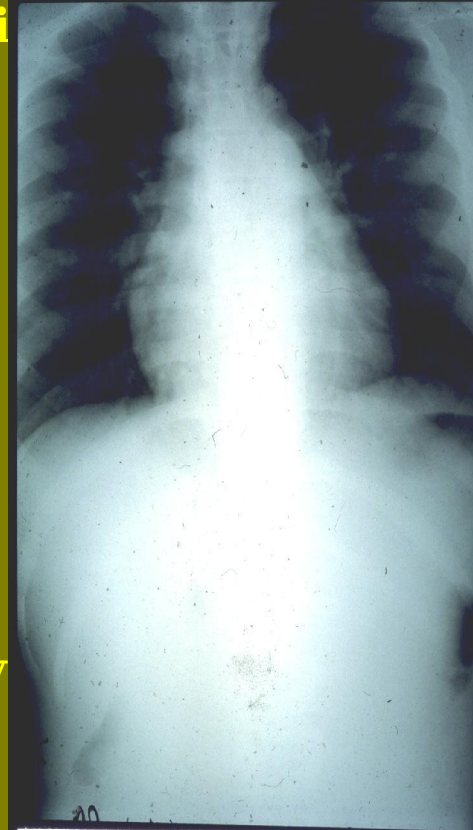
# **LUNG (CHOKING) AGENTS**

- **Toxicodynamics: Peripherally acting lung irritant, acylation at alveolar-capillary membrane, leakage of fluid into interstitial portions of lung**
- **Clinical effects: after latent period of 20 minutes to 24 hours (dose and exertion dependent) worsening respiratory distress (dyspnea, SOB, chest tightness, etc)**



# LUNG (CHOKING) AGENTS

- CXR, pulse ox, ABG useful if avail
- Treatment
  - Terminate Exposure
  - Execute ABC's
  - Enforce Rest
  - Manage airway secretions and treat/prevent bronchospasm
  - Prevent/treat pulmonary edema
  - Prevent/treat hypoxia
  - Prevent/treat hypotension



# CLINICAL CORRELATIONS

- Teflon and other highly polymerized organofluoride polymers are widespread (interiors of military vehicles)
- Perflouroisobutylene (PFIB) is a high temp pyrolysis product of Teflon, etc,
- Inhalation of PFIB: latent period 1-4 hours, progressive pulmonary edema symptoms peak at 12 hours
- Also Nitrogen Oxides, Phosphorus & Zinc Oxide Smokes



# **CYANIDE (BLOOD) AGENTS**

- **Hydrogen cyanide (AC) and Cyanogen chloride (CK)**
- **French used 4000 tons in WWI, Germans used Zyklon B in gas chambers**
- **Nonpersisient agents with LCt50 2500-5000 mg-min/m<sup>3</sup>, skin LD50 100 mg/kg, has faint bitter almond or peach kernel smell**



# World Trade Center, NYC

February 26, 1993



6 civilians killed, over 1000 injured!



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# World Trade Center, NYC

**February 26, 1993**

Sodium cyanide was used in the incident, but failed to vaporize as planned.



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# CYANIDE AGENTS

- **Mechanism of Action: CN ion rapidly combines with ferric ions in cytochrome oxidase a3, inhibiting intracellular oxygen utilization by mitochondria, anaerobic metabolism leads to massive lactic acidosis.**
- **Clinical symptoms relate to degree of cellular anoxia (hypoxia)**



# CYANIDE AGENTS

- **Moderate from low concentration:**  
transient increase in rate and depth of breathing, dizziness, nausea, vomiting, headache
- **Severe from high concentration:**  
transient increased rate and depth of breathing (15 sec), convulsions (30 sec), cessation of respiration (2-4 min), cardiac arrest (4-8 min)



# CYANIDE AGENTS

- **Management**
  - Remove from agent
  - 100% oxygen, supportive care
  - Methemoglobin formers (amyl nitrite, sodium nitrite, dimethylaminophenol )
  - Sodium thiosulfate (forms thiocyanate in liver catalyzed by rhodanase, renally eliminated)
  - ?Chelating agents (Kelocyanor, Vit B12a)



# CYANIDE AGENTS

- **Mass casualty triage**
  - **Immediate:** presents within minutes with convulsions or recent apnea but circulation intact, give antidotes
  - **Minimal:** mild effects, no longer in contact
  - **Delayed:** recovering from mild effects
  - **Expectant:** apnea with circulatory failure
- **Return to duty, mild to moderate 24 hours, severe 48 hours.**



# CLINICAL CORRELATION

- Behind CO poisoning, the second leading cause of death from smoke inhalation in fires is cyanide. Burning plastics and many other synthetic materials generate cyanide gas. A patient symptomatic from smoke inhalation who does not respond to treatment for CO, should be considered for treatment for CN (thiosulfate).



# BLISTER AGENTS

- **Mustards - Sulfur Mustard (H, HD), Nitrogen Mustard (HN1, HN2, HN3)**
- **Lewisite - L**
- **Phosgene Oxime (CX)**
- **Combinations - Nitrogen Mustard and Lewisite (HL)**
- **Used for 18 months but responsible for 40% all nonlethal casualties in WWI; for every patient, 3 more patients who thought they were exposed who weren't**





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# MUSTARD

- Sulfur mustard first made in early 1800's
- Oily yellow-brown liquid, odor of garlic, onion or mustard, freezes at 57 F, lower if mixed with L, above 100 F definite vapor hazard
- Immediate danger to life or health level is 0.003 mg/m<sup>3</sup>, LCt50 1500 mg-min/m<sup>3</sup> w/o mask, LCt50 10,000 mg-min/m<sup>3</sup> w/mask, LD50 liquid on skin 100 mg/kg, as little as 10 mcg will cause a vesicle



# MUSTARD

- **Mechanism of Action: Dissolved mustard forms very reactive cyclic ethylene sulfonium ions that bind to intracellular and extracellular enzymes, proteins and other cell components; DNA alkylation and crosslinking in rapidly dividing cells; leads to cell death and inflammation**



# MUSTARD

- **Clinical Effects**

- **Eye - most sensitive area, irritation, conjunctival injection, blepharospasm, photophobia, pain, scarring**

- **WWI mild conjunctivitis 75% of eye injuries, recovery in 1-2 weeks**
    - **15% blepharospasm, edema, orange peel roughening of cornea, recovery 4-6 weeks**
    - **10 % severe corneal involvement, 1% permanent blindness**



# MUSTARD

- **Clinical Effects**

- **Skin - Warm moist areas most affected, erythema 2-48 hours after vapor, small vesicles coalesce into blisters/bullae, clear fluid, liquid exposure forms blisters with central zones of coagulation necrosis**
- **Pulmonary - mucosal necrosis, begins in upper airways, hemorrhagic pulmonary edema in very severe exposures, resp failure/obstruction is most common cause of death**



# MUSTARD

- **Clinical Effects**
  - **GI - nausea, vomiting, bloody diarrhea**
  - **CNS - sluggish, apathetic, lethargic**
- **Time course**
  - **Mustard causes damage within several minutes of contact without causing clinical effects**
    - **Severe - Severe cough, SOB 2-4 hours, blisters within 2-4 hours, severe eye symptoms 1-2 hours**
    - **Mild to Moderate - Sneeze, runny nose, cough 12-24 hours, Red eyes swollen lids 3-6 hours, skin erythema 12-24 hours**



# MUSTARD

- **Management**

- **Skin -treat for burns, ? unroof blisters, denuded areas irrigated 3-4x q day, modified Dakins solution used in Iranian casualties and WWI, antibiotic cream (silvadene,etc), liberal analgesics, antipruritics, fluids (not as many as thermal)**
- **Eyes - topical abx, homatropine, prevent adhesion, steroids?**
- **GI - anticholinergics or phenothizaines for N,V, prolonged vomit or profuse diarrhea poor prognostic sign**



# MUSTARD

- **Management**

- **Pulmonary** - Cough suppressants and vaporizer for upper airway symptoms, fever with cough common on day 2, but infection uncommon, rx infiltrates & positive sputum, intubate early for laryngospasm /edema, bronch for pseudomembranes, O2 esarly PEEP may be helpful, treast bronchospasm, death usually between days 5-10 because of pulmonary insufficiency and infection
- **Bone marrow** - sterile gut with abx, transplant, GCSF ?



# MUSTARD

- Triage of mass casualties
  - <5% BSA skin lesions, no vital areas (face, etc) are **minimal**
  - few % to 50% BSA **delayed** if no airway problem
  - **immediate** patients have moderately severe to severe pulmonary signs and symptoms if resources available
  - If greater than 50% BSA or severe pulmonary s/s less than 6 hours after exposure are **expectant**





# LEWISITE (L)

- **Named for Dr. Wilford Lewis who synthesized it in 1918**
- **An oily, colorless liquid with the odor of geraniums**
- **Arsenic containing compound with unclear mechanism of action (combines with thiol groups)**
- **Nasal irritation at 8 mg-min/m<sup>3</sup>, Odor noted at 20 mg-min/m<sup>3</sup>, vesication noted with 14 mcg, LD50 on skin is 400 mg/kg**



# LEWISITE (L)

- **Clinical Effects (based on animal data)**
  - Skin - grayish dead epithelium in 5 min, erythema and blister within hours, full lesion noted at 18 hours, more necrosis than mustards
  - Eye - immediate pain and blepharospasm, edema, erythema, quickly swollen shut, iritis, corneal sloughing
  - Respiratory - Extreme irritation to nose, upper airway, o/w like mustard



# LEWISITE (L)

- **Clinical Effects (based on animal data)**
  - Other - permeable systemic capillaries, hypovolemia, shock, prominent GI effect, direct renal necrosis
- **Management**
  - Remove agent
  - Same as mustard, more fluids
  - BAL (dimercaprol)
- **Triage - Same as Mustards**



# PHOSGENE OXIME (CX)

- An urticant that causes a corrosive type of skin and tissue lesion.
- Solid below 95 F, vapor pressure enough to cause symptoms, very irritating.
- Inhaled: LCt50 1500-2000 mg-min/m<sup>3</sup>
- On skin LD50 25 mg/kg



# **PHOSGENE OXIME (CX)**

- **Clinical effects**
  - **Skin - pain on contact, blanching, then erythematous ring in 30 sec, wheal in 30 min, necrosis after, extreme pain persists for days**
  - **Eyes - extreme pain**
  - **Pulmonary - Irritating to upper airway, pulmonary edema**
  - **Other - hemorrhagic changes in GI tract**



# **PHOSGENE OXIME (CX)**

- **Management supportive for burns**
- **Triage in mass casualties, most patients are delayed with treatment for pain with morphine injector, patients with corrosive airway lesions are likely expectant**



# CLINICAL CORRELATION

- One of the first chemotherapy agents used was mechlorethamine (HN2, Mustargen). When this agent infiltrates out of an IV site, a classic blister agent burn occurs.



# NERVE AGENTS

- Developed in pre-WWII Germany
  - GA - Tabun
  - GB - Sarin
  - GD - Soman
- Class V chemicals developed in 1950's
- LCt50's range from 50 (VX) to 400 (GA) mg-min/m<sup>3</sup>, LD50's on skin range from 10 mg (VX) to 1700 mg (GB)





# Tokyo: Sarin Nerve Agent Attack



March 20<sup>th</sup>,  
1995

Sarin (nerve agent) released into Tokyo  
Subway System → 12 killed + 5,500 sought  
medical care.



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# NERVE AGENTS

- **Mechanism of Action: Acetylcholinesterase inhibitors (ACHase I)**
  - **MUSCARINIC:** Salivation, lacrimation, sweating, rhinorrhea, bronchorrhea, GI symptoms, wheeze, miosis
  - **NICOTINIC:** muscle fasciculations, cramps, weakness, paralysis, respiratory failure
  - **CNS:** anxiety, restlessness, ataxia, seizure, coma
- **Agents “age” (bind irreversibly) to ACHase at different rates, Soman very fast, VX slow**



# NERVE AGENTS

- **Findings depend of amount/route of exposure**
  - **Small to moderate vapor - miosis, conjunctival injection, rhinorrhea, pulmonary signs**
  - **Moderate to severe vapor - copious secretions, generalized muscle fasciculations, twitching or seizure activity, LOC, apnea, cyanosis hypotension, bradycardia, death**
  - **Liquid on skin - sweating, blanching, fasciculations at site, followed by GI effects, then same as severe vapor if significant amount**



# NERVE AGENTS

- **Management: Self and buddy aid!**
  - Decontamination
  - Ventilation - artificial resp a problem!
  - Atropine (2mg in MARK I)
  - Pradiloxime chloride (600 mg in MARK I)
  - Diazepam (10 mg in autoinjector)
- **Pyridostigmine (NAPP) pretreatment for Soman (30 mg q 8 hours, 2 doses for effect)**



# NERVE AGENTS

- Triage of mass casualties
  - Severe nerve agent casualty who is breathing is **immediate**, if not seizing and no LOC survival very likely
  - Vapor only walking, talking are **minimal**
  - Once casualty recovering from severe exposure and has received large antidotes, now **delayed**
  - If seizing, LOC, or apneic despite antidotes further care depends on resources



# CLINICAL CORRELATION

- **Organophosphate (OP) insecticides have the same mechanism of action as nerve agents. They tend to be much more fat soluble and patients often require much more atropine to control symptoms than do nerve agent patients. The treatment of OP poisoning is otherwise identical to that of nerve agent exposure.**



# **INCAPACITATING AGENTS**

- **Large category of agents that incapacitate but do not kill by physiologic effects, includes LSD, THC, belladonna alkaloids, etc**
- **BZ, a glycolate anticholinergic compound (Iraqi Agent 15 is same or similar agent)**



# **INCAPACITATING AGENTS**

- **Mechanism of action: Anticholinergic agent**
- **Signs and Symptoms: “dry as a bone, hot as a hare, red as a beet, blind as a bat, mad as a hatter,” Delirium is striking component, onset at 1-4 hours, peak at 8 hours, may last up to 4 days.**
- **Hallucinations, lucid moments, “phantom” behaviors, “carphologia,” group imaginings, paranoia**
- **At risk for heat illness!**





# **INCAPACITATING AGENTS**

- **Management**
  - **Remove from exposure**
  - **Control and contain from self harm, harm to others**
  - **Control hyperthermia, tachycardia**
  - **Physostigmine, short acting versus agent**
- **“Take his weapon away and tie him up under a tree”**



# CLINICAL CORRELATION

- If one was to accidentally inject with an atropine autoinjector, 2 mg atropine are delivered...anticholinergic symptoms will occur. Other compounds causing this toxidrome: antihistamine OD, belladonna, certain mushrooms, etc.



# **RIOT CONTROL AGENTS**

- **NOT Chemical Weapons**
- **CS - Chlorobenzylidene Malonitrile**
- **CN - Chloroacetophenone**
- **DM - Adamsite, Diphenylaminearsine**
- **RC agents used since pre WWI, CS standard NATO agent.**



# **RIOT CONTROL AGENTS**

- **Clinical Effects:**
  - **Eye - burning, irritation, tearing, blepharospasm, photophobia**
  - **Skin - burning, erythema**
  - **GI Tract - gagging, retching, vomiting**
  - **Airways - sneezing, coughing, tightness in chest, secretions**
  - **Nose - rhinorrhea, burning pain**
  - **Mouth - Burning of mucous membranes, salivation**



# **RIOT CONTROL AGENTS**

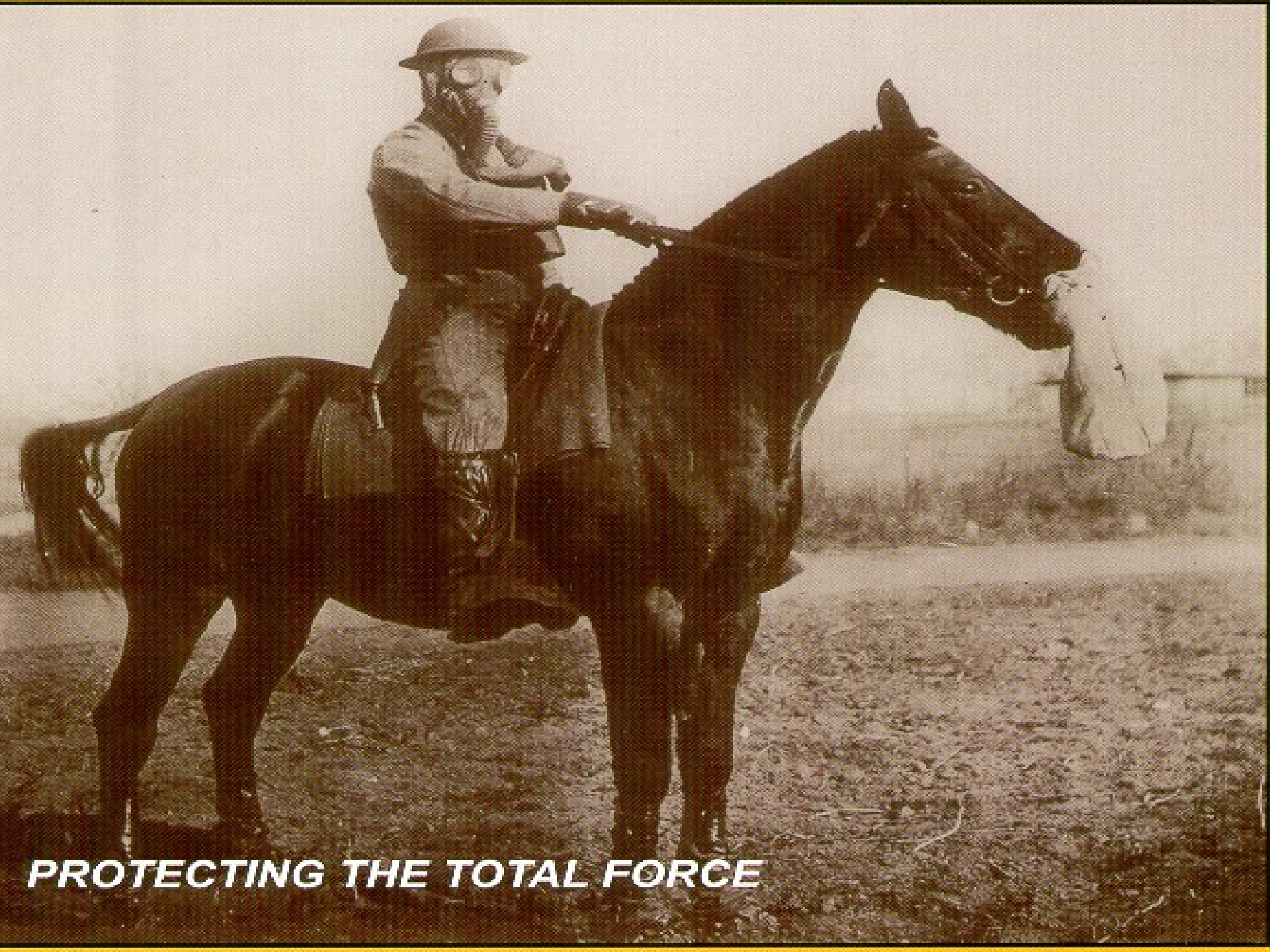
- **Management**
  - Self limiting symptoms, less than 1% of exposed pts will seek care
  - Agents may exacerbate chronic or latent pulmonary disease, rx with O<sub>2</sub>, bronchodilators, admit for observation for 12-24 hours
  - Skin lesions may have symptomatic soothing agents (calamine, etc)
- **Screen for respiratory disease and possible pregnancy if going to chamber**



# CLINICAL CORRELATION

- **Commercially available EnGard and Mace self defense sprays contain the riot agents CS and CN respectively.**





**PROTECTING THE TOTAL FORCE**

# EQUIPMENT

- **Individual Protection**
  - **M17A2 (field) Protective Mask**
  - **M24 (air) and M25A1 (tank) Masks**
  - **M40 (field) and M42 (vehicle) Masks**
  - **Battle Dress Overgarment (BDO, DBDO)**
  - **Chemical Protective Gloves and Overboots**





# EQUIPMENT

- **Individual Decontamination**
  - **Decon Kit, Skin: M291 - six packets of a mixture of activated resins that adsorbs liquid agents**
  - **Decon Kit, Individual equipment: M295**
  - **Decon Kit, Skin: M258A1**



# USEFUL REFERENCES

- **Medical Aspects of Chemical and Biological Warfare, Textbook of Military Medicine, 1997**
- **NAVMED P-5059 (NATO Handbook, 1996)**
- **NAVMED P-5041 (Field Manual, 1995)**
- **Medical Management of Chemical Casualties, 2nd Ed, USAMRICD, Aberdeen, MD, 1997**
- **Medical Response to Chemical Warfare and Terrorism, 3rd Ed, USAMRICD, 1998**



# USEFUL COURSES

- Medical Effects of Nuclear Weapons, AFRRI
- Medical Effects of Chemical & Biological Weapons, USAMRIID/USAMRICD
  - Resident Course - Aberdeen/Ft.

Detrick

USEFUL

VTC Terrorism Course - Chem each

WEBSITE

Bio each May

<https://dumc.med.navy.mil/MED27/open>

er.htm



# RECOMMENDATIONS

- Meet with your NBC Officer and schedule PME and exercises on a quarterly basis
- Cross train NBC Marines with corpsmen.



# QUESTIONS?



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